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Reforestation Of Strip-Mined Lands In West Virginia

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FOREST SERVICE

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REFORESTATION OF STRIP-MINED LANDS IN WEST VIRGINIA

by

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INTRODUCTION

THE EARLY 1940'S WITNESSED a striking increase in strip-mining throughout the eastern coal region. West Virginia, with its extensive coal resources, naturally was caught in the full current of this shift in mining methods. Today the raw gash on the hillside--almost infallibly the mark of a strip-mine operation--is a familiar sight in the State.

More than half of the State's 55 counties have some stripping operations. The West Virginia Department of Mines reports (as of December 1950) 31,250 acres covered by strip-mine permits issued since 1945. No acreage figures are

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available for stripping done prior to that year. Probably the total affected area in the State runs close to 50,000 acres.

Strip-mining got its sudden impetus about 10 years ago from the war-induced demand for coal--coupled with a shortage of labor--and the curtailment of domestic construction, which left excavating equipment idle. Stripping soon proved to be a lucrative use for that equipment. Subsequently, bigger and better stripping machinery was developed. Much coal near the outcrops can be strip-mined at lower cost than by underground methods, and some of it would be difficult to recover at all except by stripping. So in all likelihood, strip mining is here to stay as long as there are coal deposits that can be reached by surface operations.

Strip-mining operations create some unique problems. They leave the site bare, subject to erosion, and entirely unproductive, thereby creating problems in soil stabilization and land use. These stripped areas are unsightly on the landscape. Because of washing and the unfavorable character of the surface material, natural revegetation usually is slow; for many years it is inadequate for controlling runoff and erosion. In some places erosion of lower lands may be accelerated by runoff from the strippings, and siltation of lower drainage channels may occur.

As the land-use problems incident to strip-mining became evident, West Virginia set up legislative controls. The first regulatory legislation was passed in 1939. Strip-mining in the State is now done under a legislative act passed in 1945; it requires, among other things, regrading of lands formerly in agricultural use, provision for drainage, and planting of trees, shrubs, grasses, or vines as the landowner may choose. A compliance bond of $500 per acre (minimum $1,000 for any one operation) is required. The director of the Agricultural Experiment Station and the chief of the State Department of Mines jointly share the regulatory responsibilities, the former being chiefly responsible for the provisions pertaining to revegetation.

Experiments in spoil-bank revegetation with grasses and legumes were started by the Agricultural Experiment Sta-

SOIL CONSERVATION SERVICE PHOTO

Figure 1.--Strip-mining operations like this leave a telltale mark on the landscape: a bare gash, subject to erosion and entirely unproductive. The areas stripped for coal in West Virginia probably add up to 50,000 acres.

tion in 1944. Reports on this work have been published[2] and the findings have served as a basis for seeding specifications on spoils where the owner desired restoration to pasture. These investigators recognize that such seedings at best accomplish little more than to stabilize the soil and partially obliterate the scar on the landscape. First-class pasture is not to be expected in such places unless the farmer follows up with further work and investment in soil rehabilitation.

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[2] TYNER, EDWARD H., AND SMITH, RICHARD M. THE RECLAMATION OF THE STRIP-MINED COAL LANDS OF WEST VIRGINIA WITH FORAGE SPECIES. SOIL SCI. SOC. AMER. PROC. 10: 429-436. 1945.

TYNER, EDWARD H., SMITH, RICHARD M., AND GALPIN, SIDNEY L. RECLAMATION OF STRIP-MINED AREAS IN WEST VIRGINIA. AMER. SOC. AGRON. JOUR. 40 (4): 313-323. 1948.

Although revegetation to trees appears to be the best form of land use for many--perhaps most--of the stripped areas, no studies of tree establishment on strippings had been completed in West Virginia. In the northern part of the State a few test plots have been put in by the State Agricultural Experiment Station, but no reports on them have been published. In the southern part of the State coal companies have tried a number of species from time to time. Work being done in neighboring states provided some guidance, but how well that work fitted local conditions was uncertain. Demands were increasing for more precise information on conditions of West Virginia strippings as they related to tree establishment, and for planting recommendations.

Accordingly an exploratory study was undertaken by the Northeastern Forest Experiment Station to survey the situation and to assemble information about the possibility of planting trees on the spoil banks. The study included examination of such earlier plantings as could be found; but it did not include planting tests or other long-term experimentation.

The general objectives were to ascertain: (1) the conditions pertaining to plant growth that prevail on West Virginia strippings; (2) the nature and extent of natural revegetation; (3) the condition of existing tree and shrub plantings; (4) the influence of such spoil properties as acidity, texture, proportions of soil and rock, and spoil age upon survival and growth of different species; and (5)--the ultimate objective--to distill, from these local observations and from research in neighboring states, dependable recommendations for establishing forest trees on West Virginia strip-mine spoils.

Field work for the study[3] was done in 1949. This paper[4] is a summary of the findings. It includes recommen-

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[3]The authors gratefully acknowledge the assistance of Sidney L. Galpin and Edward H. Tyner of the West Virginia Agricultural Experiment Station; Paul H. Price, State Geologist for West Virginia; John Hall, West Virginia Department of Mines; Gus Tryon, Department of Forestry, West Virginia University; John Tillinghast, consulting forester; Frank Hallstead, forester for the New River Coal Company; R. L. Rowland and R. O. Smoot, rangers, Monongahela National Forest; and Soil Conservation Service personnel throughout West Virginia.

[4]The authors are also indebted to William E. McQuilkin, planting specialist on the staff of the Northeastern Forest Experiment Station, for helpful review and assistance in preparing this report.

dations that may serve as guides in reforesting these strip-mine spoils.

PROCEDURE

A LIST OF STRIPPINGS to be examined on the ground was drawn from records of the State Department of Mines according to these general specifications:

- 60 percent of the areas to be in the southern, predominantly forested section of the State; 40 percent in northern, predominantly agricultural section.
- Areas to be distributed among counties in approximate proportion to the amount of strip mining in each.
- Areas to be selected by age of spoil according to a calculated bias, giving greatest weight to those 5 or more years old, intermediate weight to the 3- to 5-year class, and least weight to those less than 3 years old.
- All areas known to have been planted to trees or shrubs by 1948 to be examined.
- Within the general pattern here specified, areas to be selected at random.

The selected list, though followed for the most part, was not rigidly adhered to in the field. Sometimes designated strippings could not be found; so others of similar age in the vicinity were substituted. Also, several strippings of special interest were added, notably some old ones antedating the Department of Mines' records.

All together, 105 unplanted strippings varying from less than an acre to several acres in size were examined for data on natural revegetation and related factors. The usual practice was to consider each area in its entirety without use of sample plots or strips; however, on some of the larger areas intensive study was made of representative portions.

Only 10 strippings were found on which trees or shrubs had been planted. Most of these plantings included several species and some obviously were considered experimental, with a variety of species and mixtures. Each species or condition, some occupying only a fraction of an acre, was

examined individually. Data were taken for entire plots if they were small; if large, certain items such as survival were estimated from representative portions. Data were recorded for a total of 53 plots on the 10 areas.

On each site or plot examined for either natural or artificial revegetation, data were obtained on location, history, physiography, physical properties of the spoils, acidity, grading, or other treatments, and amount and kind of natural plant cover. Special attention was given to size, age, and density of tree species. Where trees or shrubs had been planted, records were made of species and age of stock, method and date of planting (or seeding), survival, growth, and pertinent miscellaneous information. The descriptions and discussions to follow are based largely on these original data.

CHARACTER OF STRIP-MINED LANDS

Physical

BECAUSE OF THE MOUNTAINOUS topography, most West Virginia strippings take the form of a narrow cut on a hill or mountainside. Broad expanses of disheveled terrain, such as may be seen in some parts of the Central States and Pennsylvania, are not found here. As the mining works into a steep slope to remove the more-or-less horizontal coal seam, the overburden rapidly attains a thickness beyond which further operation is unprofitable. The exposed shelf may be less than a hundred feet wide, or at most only a few hundred feet. In length the cuts vary from a few hundred feet on dissected slopes up to several miles where they follow outcrops along the sides of smooth ridges.

The typical cut is approximately on contour. The first bites of overburden are dumped down-slope from the outcrop; later, overburden is dumped on the shelf after the coal has been removed. In profile, a typical stripping appears as a notch or terrace on a slope, the basic features being the vertical drop of the headwall and the spoil area below, which in turn drops off steeply to form the so-called outer wall or bank.

The topography within the spoil areas varies widely. Those stripped areas that have not been graded usually form a succession of short ridges or a chain of cone-shaped piles. Partial grading results in a rolling terrain. Completely graded spoils have a smooth surface sloping either toward the outer bank or toward the headwall.

Most coal seams are overlain by sandstone and shale. Soils derived from these rock formations range from fine sandy loam to clay. In some localized sections of the northern coal fields the overburden is composed of shale and limestone. Here the soil varies from silt loam to clay.

Newly formed spoils typically are composed of rock slabs and fragments intermixed in varying proportions with fine rock particles. Usually the material of the original soil mantle is buried and forms no part of the spoils surface. The surface portions of the loose spoils material are

SOIL CONSERVATION SERVICE PHOTO

Figure 2.--The typical strip-mine spoil appears as a ragged notch on a hillside. This abandoned stripping in Barbour County, West Virginia, has not been graded. Note the conical heaps of spoils material and the pool of water.

subject to maximum weathering effects and within a few years the soft shales and weaker limestones and sandstones break down into silt, clay, and sand. Although mechanical handling such as grading may contribute to the breakdown, weathering is the principal agent in this disintegration of rock into soil-size particles. Scattered chunks of more resistant limestone or sandstone may commonly be found perched on the surface long after most of the other rock material has disintegrated.

Some compaction of the spoil surface usually takes place, due to the effect of time and weathering, especially if there is a high proportion of clay-size particles. Excessive compaction, however, is usually an effect of grading. Tyner reports that grading often compacts spoil surfaces to depths of 18 to 24 inches.

Although erosion is of some concern on all unvegetated spoils, it is most serious on those that have been completely graded, and especially on those that are sloped outward from the headwall. In many places agricultural land, roads, railroad right-of-ways, and streams have been seriously affected by materials eroded from spoil banks. Damage may be done not only by water-borne sediments, but also by mass sloughing and slipping from the outer edges of graded terraces. Galpin [5] points out that steep, loose spoil--the usual condition where no grading is done--seldom erodes seriously unless water collected from other areas passes over it. However, some runoff is likely even from ungraded spoils, and if that runoff becomes concentrated anywhere, there erosion will occur.

Surface drainage on completely graded spoils often is poor. Depressions left by careless grading, or resulting from unequal settling after grading, are common. Some of these become sizable swamps that support cattails and other aquatic plants; others are mere intermittent puddles. Many of the spoils that have not been completely graded contain year-round bodies of water. Though these are mostly small pot holes, they range in size up to ponds of several acres and in depth to more than 8 feet.

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[5] Galpin, Sidney L. Discussion of regulation of strip or open cut coal operations. W. Va. Coal Mining Inst. Proc. 39: 24-28. 1946.

The permeability of spoils made up of shale--or of limestone and shale--apparently decreases with age as weathering produces increasing amounts of fine-textured soil. The prevalence of excessive erosion and standing water on graded surfaces of this type of spoil indicates that mechanical compaction may be particularly significant here in reducing permeability. With coarser soil material, permeability seems to be less affected by grading.

Chemical

The spoils material is consistently low in nitrogen, and in some instances phosphorous may be lacking.[6] However, since trees in general are better adapted to infertile soils than most other plants, and moreover, since many species of trees seem to grow under the poorest fertility conditions found on spoil banks, our survey did not include data on soil fertility. Of the chemical factors, we focussed attention on soil acidity.

West Virginia spoils are from medium to strongly acid, as is generally true of coal stripping spoils everywhere. The highest pH observed was 6.5 (only slightly acid) and the lowest was 3.5 (extremely acid). Two percent of the areas tested showed pH values higher than 5.5; 93 percent ranged from 4.0 to 5.5; and 5 percent were lower than 4.0.

Most spoils with pH of 5.5 or higher were composed of a mixture of limestone and shale materials. Apparently these were undergoing a period of active acidulation in which the normally high pH values of the limy materials were reduced by the acid from high-sulfur coal and pyritic rock particles. This was indicated by the fact that natural mineral soils adjacent to these strippings showed a mildly acid or even an alkaline condition.

Tyner reports that some spoils show a wide pH variation within a relatively small space. In our investigation most of the extreme variations on individual spoil banks were found in the northern section of the State where the overburden often contains acid-forming pyritic material.

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[6] Limstrom, G. A. Extent, character, and forestation possibilities of land stripped for coal in the central states. Central States Forest Expt. Sta. Tech. Paper 109. 79 pp. 1948.

Most of the coal is from the Pittsburgh seam and it too is generally high in sulfur.

In the southern section, where the stripped coals have a comparatively low sulfur content, pH values averaged around 4.5 within a relatively narrow range of variation.

HOW CHARACTERISTICS OF SPOILS MATERIAL INFLUENCE REVEGETATION

EXPERIMENTAL WORK done in other states has shown that such factors as grading, age of spoil, its composition and acidity influence the revegetation of spoil banks. The spoils in West Virginia were sampled to determine the importance of these factors so that revegetation studies done elsewhere could be related to conditions here. An analysis was also made of the effect of these factors on tree revegetation in West Virginia; but because almost all tree plantings on spoil banks here are so young, and the plantings so few, this aspect of the study was inconclusive.

Grading

Analysis of the data on grading indicates that complete grading may adversely affect the natural revegetation of West Virginia spoils. Partially graded banks seem to revegetate about as well as ungraded ones.

On completely graded spoils, natural revegetation was only about one-fourth as plentiful as on ungraded and partially graded spoils when other conditions such as age, soil material, and location with respect to seed source were similar. Certain factors were observed that are at least partly responsible for this condition: (1) On ungraded or partially graded banks the rougher surface is more favorable for the lodging of seeds. (2) The surface material of ungraded banks provides a looser, more favorable seedbed for germination. (3) In general, the upper few inches of material in ungraded and partially graded banks is moister. (4) Information received from several mining engineers and foresters who have checked temperatures on spoil surfaces indicates that higher summer temperatures are found on the graded areas.

Investigations in the Central States indicate that water conditions may be better in ungraded spoils. Limstrom reports that no evidence of beneficial effects to artificial tree revegetation from grading has been found, whereas there are definite indications that, on spoils containing a high proportion of clay, grading affects tree growth adversely. Tyner found that certain grasses and herbaceous legumes established on completely graded spoils in West Virginia suffer losses during prolonged dry periods. These losses apparently are caused by failure of the roots to penetrate the compacted materials as rapidly and deeply as they do the looser, ungraded spoil.

Although this study indicates that grading is definitely detrimental to both natural and artificial revegetation, Bramble[7] found just the opposite in central Pennsylvania. However, pending further study, it seems best in West Virginia to grade spoil banks only partially or not at all where trees are to be planted.

Spoil Age

The age of a spoil area, or the length of time since it was last disturbed, was found to have a significant effect on the amount of plant cover. Cover generally increased with age on both graded and undisturbed spoils, but at different rates.

On 1-year-old ungraded areas with pH values exceeding 4.0, the proportion of the surface covered with plants averaged about 8 percent; on similar 3-year-old areas the average was about 48 percent. After 3 years the rate of increase tapers off, but most 5-year undisturbed spoils are more than 50 percent covered.

In contrast, 1-year-old graded spoil areas in the same pH range showed only about 2 percent cover, and at 3 years, about 12 percent. Not enough 5-year graded spoils were examined to provide a good average; the few that were seen conformed to the same trend, the cover being considerably sparser than on ungraded spoils of the same age.

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[7] Bramble, W. C. Correspondence. 1951.

Physical Soil Composition

Limstrom found in the Central States that the texture of the soil fraction(particles 2 mm. and smaller) in the spoils material and the ratio of soil to rock greatly affected both survival and growth of forest plantations. Where the soil fraction is mostly sand, water-retaining capacity and fertility are low and only the most drought-resistant species will succeed. Where the content of clay is high, water-retaining capacity and fertility are higher, but internal drainage and aeration are likely to be poor, particularly if the spoil has been graded. Soil material of intermediate texture--loams or mixtures of sand, silt, and clay--are most favorable for tree growth.

The proportions of soil-size and rock obviously would influence water-holding capacity, aeration, and drainage. Limstrom classifies a site as dry and suitable only for the more drought-resistant species if the soil fraction is mainly sand and less than 50 percent of the volume of the soil-rock mixture; or if loamy and less than 40 percent of the volume; or if clay and less than 30 percent. Bramble[8] recognizes soil-rock ratio as one of the site factors but evaluates it less critically, stating that spoil material will support tree growth if 20 percent or more is in soil-size particles.

Analysis of the data collected in this study failed to show any definite influence of texture of the soil fraction or of soil-rock ratio on the degree of natural revegetation or on growth rate of trees. This is no contradiction of Limstrom's findings. The explanation is that, on most of the West Virginia study areas, the soil fractions were texturally similar, ranging from very fine sandy loams to silt loams. Also, the soil-rock ratios on the study areas as a whole ran so nearly alike that no relationships with plant growth could be isolated. Had intensive studies on small selected plots been made, evidence of such relationships probably would have been found.

Although the West Virginia spoils are rather uniform texturally, there are some of more sandy texture and some

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[8]Bramble, W. C., and Ashley, R. H. Progress report on spoil bank planting--fall 1949. Pa. State Coll. School Agr., Agr. Expt. Sta. Progress Rpt. 24. 6 pp. 1950.

with a relatively high clay content. Too few of these were represented in our data to permit reliable comparisons, but their existence in the State should be recognized. Limstrom's observations in the Central States regarding droughtiness of sandy spoils and the unfavorable conditions of aeration and drainage on clay spoils certainly would apply without qualification in West Virginia.

Acidity

On spoils with a pH lower than 4.0, less than 1 percent of the area had revegetated naturally. There were no trees and only a few herbaceous plants such as pokeweed, cinquefoil, poverty grass, and blackberry. Limstrom also observed that pH 3.8 is lethal to most common plants, and that only a few species will grow where the pH is lower than 4.0.

Spoils with a pH value of 4.0 or higher were generally found to be seeding in naturally with herbaceous, shrub, and tree species. A statistical analysis to ascertain the effect of pH on ground cover indicated that, within the limits of our data, changes in pH above 4.2 had no significant effect on the amount of ground cover.

NATURAL REVEGETATION

NATIVE PLANTS NORMALLY begin to invade spoil areas soon after strip-mining operations cease and, unless inhibited by excessive acidity (pH values below 4.0), will occupy up to half the spoil surface after 3 to 5 years. The more common herbaceous plants are pokeweed, milkweed, cinquefoil, blackberry, dewberry, greenbrier, broomsedge, and poverty grass.

Where seed trees are present on adjacent areas, particularly light-seeded species, tree seedlings usually are found on the spoils (table 1). Although occasionally tree seedlings come in quickly and in such numbers that they virtually cover the ground surface, their invasion on most areas is a somewhat delayed and gradual process. Many seedlings doubtless start every spring after a seed crop but fail to get their roots deep enough to reach adequate moisture before the weather and the spoil surfaces become hot

Table 1.--Occurrence of natural tree and shrub reproduction on strip-mine spoils in West Virginia, by number of plots

Commercial species[1]	Plots[2]	Noncommercial species[1]	Plots[2]
	Number		Number
Black locust	65	Staghorn sumac	33
Red maple	45	Black willow	19
Black cherry	33	Pin cherry	14
Sassafras	30	Dogwood	9
Yellow-poplar	30	Redbud	8
Black birch	29	Serviceberry	3
Bigtooth aspen	24	Cockspur thorn	3
Sycamore	21		
Red oak	15		
Blackgum	14		
White oak	13		
Pignut hickory	13		
Pitch pine	8		
Sugar maple	7		
White ash	7		
Beech	6		
Black walnut	5		
Chestnut	4		
Slippery elm	3		
American elm	3		
Basswood	2		

[1] Only those species are shown that occurred on more than 1 plot.

[2] Based on a total of 105 plots examined.

and dry; consequently they succumb during the first few weeks or months after germination. Planted trees, with 6- to 10-inch roots already formed, fare much better.

Random comparisons of growth of certain tree species on and off spoil areas indicated that their growth on spoil areas compares favorably with tree growth on undisturbed land. In some instances early growth, particularly of black locust, appeared to be better on the spoils. Examples were

found where young black birch, red maple, sycamore, bigtooth aspen, and yellow-poplar had made remarkable growth on spoil banks. Galpin also remarked on the surprisingly rapid growth of trees on some strip-mine spoils.

Examination of an old spoil dating back more than 30 years suggests that some spoils, at least, will sustain good growth rates of trees through several decades. Table 2

Table 2.--Growth data of trees growing on old strip-mine spoils, Preston County, West Virginia

Species	Average height	Average diameter at breast height	Average age
	Feet	Inches	Years
Sycamore	40	15	25
Black walnut	35	8	29
White ash	25	5	14
Yellow-poplar	45	12	27
Black cherry	35	11	25
Black birch	30	10	21
Black locust	35	12	25

shows the average sizes attained by trees on this spoil area, which was left ungraded after a stripping operation during the first World War.

ARTIFICIAL REVEGETATION TO TREES AND SHRUBS

AS NOTED UNDER the section on "Procedure," the data on artificial revegetation of mine spoils in West Virginia are based on only 10 areas, most of which, however, included several species and conditions, yielding a total of 53 recorded plots. Nineteen tree and shrub species were represented on those plots, but many of them appeared too few times to provide much basis for judging their adaptability. Distribution of the plantings and plots, with planting dates

Table 3.--Distribution of strip-mine plantings and study plots in West Virginia by counties, 1945-48

County	Areas planted	Date of planting	Study plots	Species used
	Number		Number	
Fayette	2	1945	7	Red and white pines, yellow-poplar, black walnut, white ash.
		1946	10	Red, white, and Scotch pines, larch, black locust.
Randolph	2	1948	2	Red pine, Norway spruce, black locust.
		1948	1	Red pine, black locust
Tucker	1	1948	1	Black locust.
Monongalia	1	1946	6	Red, white, and pitch pines, black locust, multiflora rose, shrub lespedeza.
Preston	1	1945 and 1947	15	Red, white, pitch, and shortleaf pines, Norway spruce, bald cypress, black locust, black walnut, red and chestnut oaks, catalpa, sand cherry, multiflora rose, shrub lespedeza.
Brooke	2	1944	1	Red pine.
		1945 1946 1947	4	Red and white pines, Norway spruce.
Taylor	1	1947	6	Red, Scotch, and Virginia pines, black locust, sand cherry.
Total	10	--	53	19 species--16 tree, 3 shrub.

and species, is shown in table 3. From such limited sources, only a few general conclusions and indications regarding effect of different factors on tree performance can be extracted.

All species of trees and shrubs included in the plantings failed where pH of the spoil was lower than 4.0, and most species showed fair to high survival where the pH was above that value. This observation, which is in accord with the findings of other investigators, points definitely to a pH of around 4.0 as the acidity threshold below which planting is futile. Since 95 percent of the spoils tested in West Virginia had pH values above this threshold and within the plantable range, acidity here is only rarely an important limiting factor.

In the few instances where observations of the same species on soils of different textures were possible, no significant differences in survival were found except with red pine on clay. Here survival was definitely lower than on spoils of coarser texture.

The average growth for most of the planted species was about the same on spoils as on undisturbed soil. In a few places, black locust and red pine on spoils showed exceptionally fast growth. Since none of the plantings was more than 4 years old, we can only speculate from the performance of naturally established trees on older spoils as to how well plantation growth rates will be sustained. Those performances generally are encouraging, particularly the example cited in table 2.

A small amount of direct seeding of red and chestnut oaks was observed. Near the end of the first growing season both survival and growth were good.

RECOMMENDATIONS FOR REFORESTATION

THE PRINCIPAL PURPOSE of establishing trees on strip-mine spoil areas is to produce cover that will, first, prevent or reduce surface runoff, erosion, and sedimentation of stream channels and reservoirs; and second, start the process of restoring the land to a productive condition.

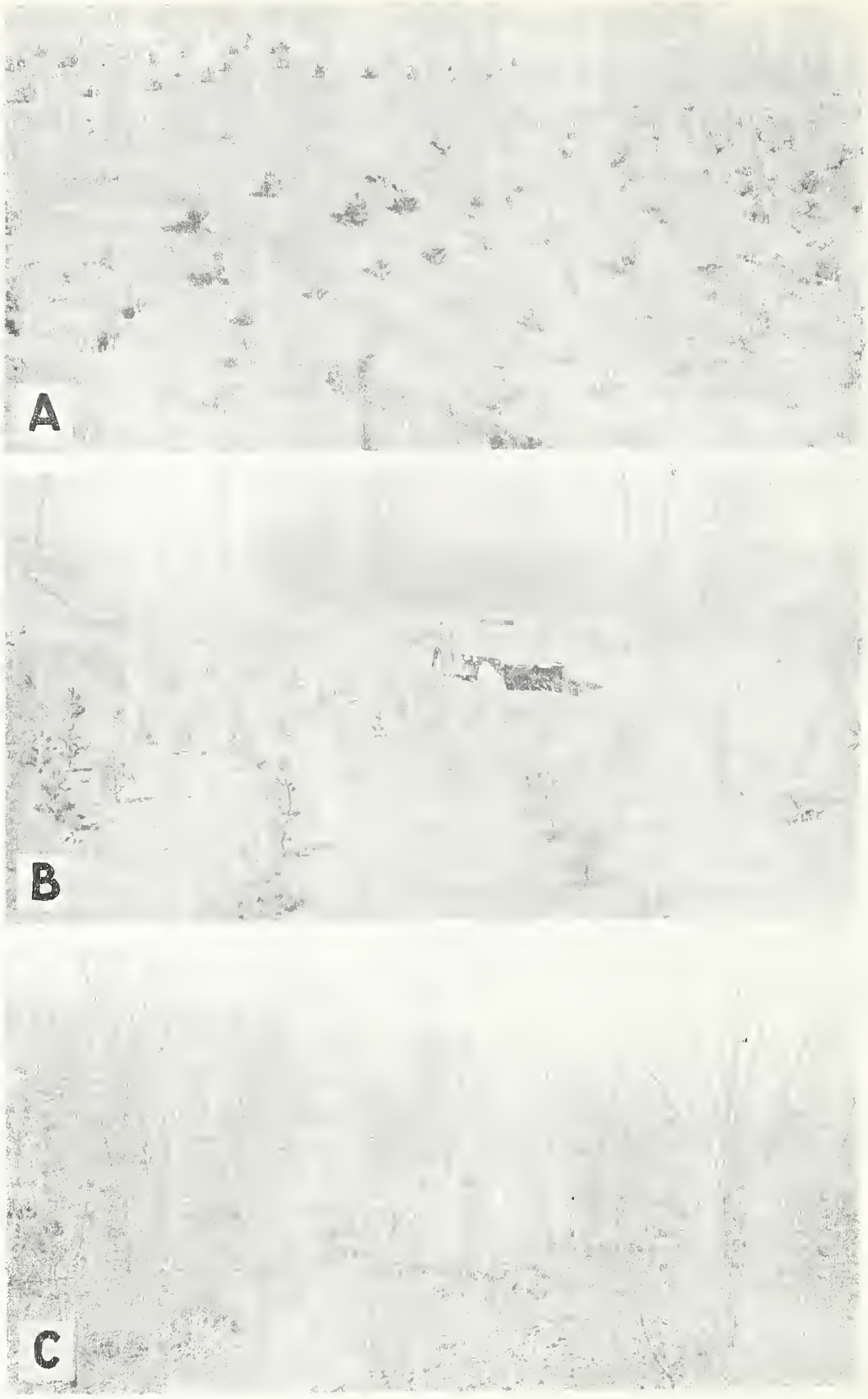

Figure 3.--These 4-year-old plantations on graded spoil banks in Fayette County, West Virginia, were planted in April 1946 by the New River Coal Company. A, red pine; B, white pine; C, black locust.

A well-stocked forest is the most practical and efficient cover known for accomplishing these ends. On steep slopes and infertile soils, trees are far superior to grasses or other herbaceous plants because, unless costly soil amendments are applied, herbaceous species seldom grow vigorously enough to provide full protection to the site.

The ultimate purpose in restoring these lands to a productive condition is, in most instances, the growth of merchantable timber. However, timber production is not emphasized as an immediate purpose of--or incentive to--planting the spoil areas of West Virginia; information on tree growth on these spoils is too meager to provide a sound foundation for predictions of growth and yield. Though some spoils undoubtedly are capable of producing good sawlog timber, growth during the first rotation on others may be only poor to fair, yielding only mine props, fence posts, and similar small products.

The aim of these recommendations is to point out some kinds of trees that seem well adapted for planting on mine spoils, how and where to plant them, and how to cope with certain of the factors that may tip the balance toward success or failure.

Site Examination

Each spoil area should, of course, be examined when planting plans are being prepared in order to determine whether or not the area as a whole is plantable, and if so, the plantable acreage. Although most spoils can and should be planted soon after mining operations cease, a substantial minority will be found on which immediate planting would be futile, or at least inadvisable. This minority will comprise mainly spoils that are highly unstable and those that are excessively acid.

Spoil stability is in part a function of age. Where a new spoil is extremely loose or where there is evidence of considerable slippage and mass movement on steep slopes, planting should be delayed for a year or two until the spoil material has settled and has assumed fairly well-fixed angles of repose. A delay of more than 2 years generally is not advisable, even though some movement persists. By that time the worst of the slipping and sloughing should be over and the situation will not be likely to improve much in the near future. The planting should then be done if the pros-

pects are at all reasonable. The longer the time lapse before revegetation, the greater the damage to adjacent lower areas, and--because of compaction--the more difficult it becomes to do a successful planting job.

Soil acidity should be tested on every spoil area before scheduling it for planting, or at least on enough areas in a locality to be sure the pH values are above the critical level. Where there is any doubt, accurate readings should be taken at several points over the area, both at the surface and at 6 to 12 inches' depth. Tree planting should not be done where the pH is below 4.0.

Acidity, like stability, is in part a function of spoil age. Most excessively acid areas tend slowly to become less acid through chemical weathering processes and leaching, and they may become plantable after perhaps 5 or 6 years.

Many plantable spoil areas include unplantable sectors which, if sizable, should be designated and allowed for in making estimates of acreage, planting stock requirements, and planting labor. Most common among these unplantable conditions are: (1) depressions where water stands for some time after rains; (2) sharp crests of ridges and piles; (3) rock concentrations with insufficient soil material to support tree growth (minimum of 20 percent soil-size particles where much of the rock is of gravel size, 30 to 40 percent where the rock is larger); and (4) spots of excessive acidity.

Spots of the same character as listed above, but too small to map or consider in planting estimates, also will be encountered frequently. Planters should be taught to recognize these situations and bypass them in planting. Excessively acid spots will be the most difficult type of situation for planters to recognize. Their presence sometimes is revealed by a moist condition of the soil surface at places where such moisture would not normally be expected. After some experience on an area, supervisors probably will find other helpful indicators.

Species

The following trees are recommended for mine-spoils planting in West Virginia where soil pH is 4.0 or higher:

Conifers	Hardwoods
Red pine Pitch pine Jack pine Virginia pine	Black locust Yellow-poplar Red maple Sycamore

This list represented our considered judgment derived from planting research in neighboring states, the meagre local experience in planting, and trends in the natural invasions of trees into spoil areas. Not all the species named have been proved in local plantings; sycamore and red maple, for instance, are included mainly because of their demonstrated adaptability as wild seedlings on spoils, and jack pine mainly on the basis of its performance in Ohio and Pennsylvania plantings. The list is open to additions and modifications as more local experience is acquired.

Three of the pines in the list probably should be restricted to certain altitudinal zones; unfortunately, not enough planting has been done in West Virginia to define those zones precisely. However, since red pine--a northern species--has proved unsuited to the relatively mild climates prevailing south and east of the Blue Ridge in Pennsylvania and Maryland, this species is at present recommended in West Virginia only at elevations above 1,500 feet. With jack pine, the climatic limitations are not so well established as for red pine, but like red pine, it is known to thrive best under fairly rigorous climates. Therefore, until future experience provides better guides, we suggest that jack pine also be restricted to elevations above 1,500 feet. Virginia pine, on the other hand, is a southern species and is at present recommended only at elevations below 2,500 feet.

Local plantings and extensive studies in Ohio and Pennsylvania indicate that a number of other species may prove to be useful in planting spoil banks in West Virginia. At present these species are suggested simply as possibilities; they are not recommended positively now for West Virginia because their suitability has not been adequately demonstrated by field-planting experience nor by widespread natural seeding-in. Some of the more promising of these species are:

Conifers	Hardwoods	
White pine	Black cherry	White ash
Scotch pine	Red oak	Green ash
European larch	Chestnut oak	Silver maple
Japanese larch	Bur oak	Cottonwood*

*Populus deltoides

Black cherry is an exception to the general characterization of the above list; it does seed in commonly on spoils in the State (table 1), but it is not recommended unreservedly because planted seedlings seem to be subject to frost injury. Although further investigation may show this defect to be avoidable by proper attention to seed origin, black cherry must for the present be listed as of uncertain reliability. Field tests on the local spoils to evaluate all the above-named species are an immediate research need.

Planting Stock

Because bare spoil areas tend to be hotter, dryer, and more windswept than most other planting situations, it is essential that the planting stock used on spoils be sturdy, robust, and well-rooted. Undersize, spindly, or weak-rooted plants commonly found in run-of-the-nursery stock will almost surely fail in large numbers on spoils.

Red pine and white pine stock should be not younger than 3 years; stock of the other suggested pines should be at least 2 years old; all should have been so grown in the nursery that the stems are stiff, relatively short, and beginning to branch. Undersize, injured, or top-heavy plants should be culled out.

Black locust customarily is planted as 1-year seedlings; the other hardwoods listed may with good nursery management be plantable at 1 year, but as a rule are of better size at 2 years. As with pines, the stems should be strong and stocky, with no suggestion of spindliness. Roots should be at least 8 inches long and well developed according to characteristics of the species. In reasonably moist situations, cottonwood may be planted as unrooted cuttings. Use cuttings 15 to 18 inches long, with a caliper of 3/8 to 3/4 inch. Plant so that one or two buds remain above ground.

Planting Methods

Hole planting is the most reliable method. Use a mattock or any of the specially designed planting hoes. Be sure that the holes are dug deep enough to accomodate the full length of root, that the backfill is firmed from the bottom up, and that the trees are planted at proper depth--about 1 inch deeper than they stood in the nursery. The side-hole procedure is easier and generally just as satisfactory as the slower center-hole method.

Bar planting is considerably faster than hole methods but is not suitable to all conditions. It does not work very well in compact stony soils, nor with roots that are much branched. For black locust and other hardwoods having a stiff, sparsely branched tap root, bar planting can be recommended wherever the spoil is reasonably loose. On steep banks where holes are awkward to manage, the bar method is much more convenient.

Good bar planting depends upon proper execution of the technique. After first inserting the bar, make one short pull on the handle to widen the slit a bit; do not rock the handle back and forth. Then remove the bar and insert the tree, making sure the roots are fully suspended; pinch the top of the slit with the toe or the bar just enough to hold the tree in place. Next, re-insert the bar 3 to 4 inches back of the first slit, pull back strongly on the handle to close the bottom, then push forward to close the top against the tree. Close the second slit by a partial third insertion of the bar, or, if the soil is loose, push it shut with your foot. Finish with a vigorous stomp of the foot on the loosened area next to the tree.

Season For Planting

The best time for planting is in early spring before new growth starts. Fall plantings often suffer heavy losses from winter killing and frost heaving.

Spacing

Because early soil protection is one of the principal objectives of planting, spacing should be reasonably close. As a general standard, 6 by 6 feet is recommended. Somewhat closer spacing--5 by 5 or 4 by 6--may be advisable on clay

spoils, particularly if graded, because mortality is likely to be higher there than elsewhere. Any prescribed spacing is a flexible specification to be fitted to the topography and surface conditions of the site. A good planter shortens the distance a bit here and stretches it there to avoid holes, ditches, sharp ridge tops, rock piles, and like places where a tree has little chance to live.

Species Arrangement And Distribution

In general, hardwoods are more sensitive to unfavorable site conditions than pines. Therefore, in planting plans involving both pines and hardwoods, the hardwoods other than black locust should be assigned to the better situations. Black locust, being valuable mainly as a soil improver and nurse cover, may be used anywhere.

On the common terrace-type of spoil area, the least favorable site condition usually is the cut sector near the headwall; here the pines are better adapted, and hardwoods other than locust should be restricted to the outer, filled portion. Even on filled sectors, pines usually offer better chances for success on the dryer, more exposed situations such as ridges, southern and western exposures, and coarse sandy soils.

Mixtures of species are generally preferable to a single species for planting--both on spoil areas and elsewhere. Mixtures provide greater assurance that some degree of success will be achieved. Black locust plays a special role in mixtures because of its faculty of fixing atmospheric nitrogen in the soil, thereby improving the site for the growth of other species. Locust also is valuable because, with its rapid juvenile growth, it begins to provide significant amounts of litter and soil protection long before most other species become effective.

Mixtures of conifers and hardwoods, or of different conifers, are best made by blocks or strips at least 30 feet wide. Otherwise, one species may grow faster and thus overtop and shade out the slower-growing trees. A convenient way to lay out such a mixture on the common terrace-type area is by strips, 5 to 10 rows wide, parallel to the headwall. A very simple and suitable pattern would be, for example, alternating strips of red pine and black locust. Or, if desired, strips of a third species could be included.

Investigators in the Central States have found that other hardwoods can be grown with black locust in intimate row-by-row or tree-by-tree mixtures, and furthermore, that the other hardwoods often do poorly on spoil areas unless so mixed with locust. On some sites, at least, the hardwoods apparently require the nitrogen and other site benefits supplied by the locust in order to thrive. As a rule, the locust greatly outgrows the other hardwoods at first, but the latter can persist for a time under the relatively light locust shade. After 8 to 12 years, the locust begins to deteriorate from the combined effects of borers and site deficiencies; the crowns open up and some borer-weakened stems may break off; then the other hardwoods push through and soon dominate the stand.

Because of the frequent failure of hardwoods in pure stands, Central States workers[9] advocate that hardwoods be planted only in intimate mixtures containing about 50 percent locust. The same practice is recommended for West Virginia.

The simplest way to put in such mixtures is by alternate rows of locust and the other species. The "other species" may be one species or a randomized mixture of two or three hardwoods, but the proportion of locust should not be reduced. Pines or other conifers should not be incorporated in intimate mixtures with locust. For a pine-hardwood mixture, a strip or block pattern would be used: alternating spaces would be planted to an intimate mixture of locust and the selected hardwoods as described above, the remaining spaces to pure pine.

Direct Seeding

Direct seeding offers some possibilities for cutting costs in spoils reforestation, but more research is needed before definite recommendations can be made. Rodents, which are one of the principal obstacles to success in direct seeding, presumably are less numerous and therefore would cause less trouble on spoil areas than on more heavily

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[9] Chapman, A. G. Forest planting on strip-mined coal lands with special reference to Ohio. Central States Forest Expt. Sta. Tech. Paper 104. 25 pp. 1944.

Limstrom, G. A., and Merz, R. W. Rehabilitation of lands stripped for coal in Ohio. Ohio Reclamation Assoc. 41 pp., illus. 1949.

vegetated sites. On the other hand, most spoils are pretty difficult sites to establish plants on from seed: heat and drought and surface washing tend to operate there with exceptional severity.

Direct seeding should not be ruled out, neither should it be anticipated as a panacea. In all probability, it eventually will be adopted in spoils reforestation, as it is elsewhere, as a supplemental method to be used only under certain restricted conditions.

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